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SCIENCE TEACHING IN ELEMENTARY SCHOOLS[1]

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What can the elementary school do in the teaching of physical science? What should be the aim, scope, and method of science work in the elementary school? What results may reasonably be expected? It is my purpose in this paper to set forth what is being done in the city of New York toward answering these questions.

About two years ago a new course in "nature-study" was planned for the elementary schools. It is stated in the syllabus:

> The aim of nature-study, particularly in the lower grades, is to cultivate a sympathetic acquaintance with nature and to develop the power of observation. To this end, the children should be brought into actual contact with the object of study whenever possible, either in or out of the classroom. The power gained by learning facts through actual observation or experiment will enable the pupils afterward to picture to themselves facts which it will be feasible to make known to them only by description. . . . The phenomena of life in the world about the pupil should be made prominent. The presentation of the topics in elementary science in the seventh and eighth years should, as far as possible, be accompanied with illustrative experiments. Classroom work should be supplemented by visits to the parks and museums, and by the use of pictures and lantern slides.

The course of study outlined in the syllabus divides itself into three cycles. In the first three years it is purely observational, consisting of lessons on familiar animals and plants, and observations of familiar natural phenomena, such as the weather, winds, clouds, storms, the sun, changes of season, etc. In the fourth and fifth years a more intensive study of animals and plants is required, together with some elementary classification. In the seventh and eighth years (the last two years of the elementary-school course) nature-study becomes "elementary science"—

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practically a complete course in elementary physics. It is this last phase of our nature-study work that I purpose to speak of somewhat in detail.

The aim of the course in "elementary science" is not only to acquaint the pupil with the fundamental laws and principles of physics, but to train him into habits of careful doing, close observation, accurate thinking, and correct expression; in short, physics is taught for its disciplinary as well as its practical value.

The scope of the course is somewhat comprehensive, as may be seen from the following outline: seventh year, first half, gravity, mechanical powers; second half, the mechanics of liquids and gases; eighth year, first half, the phenomena of sound and heat; second half, the phenomena of light, electricity, and magnetism. For the interpretation and practical operation of this course, a special syllabus has been prepared which contains a suggestive list of experiments that may be performed by the teacher and the pupils. Throughout the course emphasis is laid on the experimental presentation and development of the subject. Constant correlations with the other subjects of the grades and with the experiences in the daily lives of the children are required. It is sought not merely to make the course a collection of isolated facts, but to organize the experiences of the pupils into a connected, logical, unified whole. The practical applications and illustrations in the industries are an essential feature of the course; in fact, the keynote is found in the injunction to "make the work practical and interesting."

The time schedule calls for two periods of forty minutes each per week, but the permissible addition of a "study period" makes the available time to be given to physics three periods per week.

Many discouraging conditions were met with in the introduction of this experimental course in science into the public schools. There was no equipment whatever for the work; no apparatus was available; the classes were too large for laboratory work, and, most discouraging of all, the majority of upper-class teachers had no preparation whatever to teach properly an experimental course.

It is gratifying to note that these unfavorable conditions are being overcome as rapidly as it is possible in so vast a system of education as that of New York. There is a growing realization of the importance of natural science as a legitimate branch of the common-school curriculum. Treated at first with contempt, as another of the "fads and frills," it is now generally admitted that the study of science has a high claim for recognition as a factor in the common-school education of every boy and girl, not only as an object in itself, but as a means of general culture and discipline.

Our board of education has recognized the importance of laboratory work in science-teaching by providing for a "science room" in the plans of all new elementary-school buildings, and by placing on the supply list apparatus and material for fully equipping such a room for demonstration and individual laboratory work. In a number of the older schools regular classrooms have been equipped with demonstration tables for the teachers, and a sufficient supply of apparatus to carry on successfully a practical laboratory course.

The introduction, two years ago, of the "departmental system" of teaching into the seventh and eighth years has been a powerful aid in developing and perfecting the course in science. Under this system, each teacher becomes, to a certain extent, a specialist devoting his time exclusively to one subject, or at most to a small group of related subjects. It is thus possible, in many cases, for the principal of a school to assign the subject of physics to a teacher who has some special qualifications for the work. This system also conduces to economy of equipment and a unification of the entire course in a school. It makes possible the division of a large class into small laboratory sections, or the assignment of an additional teacher to aid in supervision and instruction.

Finally, the teachers, as a whole, are realizing the educational and disciplinary value of science instruction, and are striving, by all means in their power, to equip themselves for the work. Perhaps in no other subject of the course of study do the results to be attained depend so much upon the teacher as in the subject of elementary science. Not only must he be enthusiastic and thoroughly conversant with pedagogical method in general, but in addition, he must possess a comprehensive knowledge of the subject-matter and its technique. It is useless for a teacher to attempt to teach physics unless he can *do* as well as tell. This practical knowledge he can obtain only at first hand, as the result of his own experimental work. University and summer-school courses in practical physics are being attended by a goodly number of those teachers who feel the lack of training in laboratory methods. As a further proof of the desire on the part of the school authorities to obtain the best results in this branch of instruction, it may be stated that all applicants for license to teach in the elementary schools of the city must now pass an examination in physics.

It will be seen from this rapid survey of the field that much has already been accomplished toward the establishment of a rational course in physics in the elementary schools, and that the outlook for future development is very bright.

Regarding the method of teaching physics to be followed in the elementary school, it is my opinion that the work should be conducted along three lines: (1) presentation or demonstration by the teacher, assisted, whenever practicable, by some pupil or pupils; (2) individual laboratory work by the pupils; (3) recitations upon the topics of the demonstration or laboratory work. Let us consider briefly these three phases.

1. It is assumed that the school has an ample equipment of apparatus and material to enable the teacher to present experimentally the fundamental principles of the science. Every experiment to be performed by the teacher before the class should be rehearsed carefully in private, no matter how simple it may appear or how often it has been done before. The teacher, when he stands before his class, should have absolute confidence in the successful outcome of the experiment he performs. Nothing can be more subversive of the aims of science-teaching than the exhibition of an experiment performed in a bungling manner. An occasional failure may occur, even when the teacher has the highest technical skill. In such a case, no particular harm is done; in fact, the failure may prove even more instructive than a successful outcome, provided the teacher retains his composure and quickly turns the attention of his class to a careful examina-

tion and consideration of the new and unexpected phenomena observed.

During an experiment (which should always be performed with deliberation, never in a hurry) the teacher should, by skilful questioning, guide and direct the attention of his pupils, and stimulate their observing and reasoning powers. Toward the end of the period the teacher should write on the blackboard an outline giving in concise form the object, method, results, and applications of the experiment. This may be copied by the pupils in their notebooks, together with a sketch or diagram of the apparatus. I would not let the pupils of the seventh year take notes during the progress of a demonstration. It is my experience that pupils at this age (about thirteen years) are too young and unprepared to take notes intelligently in this way. Their attention is divided between the experiment and the notebook, and the lesson of the experiment becomes obscured or lost entirely. Besides, a habit of scribbling is easily formed, and may seriously cripple their work in other departments. With the eighth-year pupils I would omit the outline on the blackboard, but would pause in the demonstration, at frequent intervals, to enable the pupils to record observations and inferences, and to arrange their notes logically and neatly. All this may seem like doing too much for the pupil, but experience has shown me that the average pupil of thirteen to fourteen years needs much more help than the teacher is apt to realize.

As to the kind of experiments that should be performed by the teacher, I would say that, in general, he should perform: (*a*) experiments that may be considered basic or typical; (*b*) experiments that are wholly, or almost wholly, qualitative in character, and which it would be a waste of time to have each pupil perform; (*c*) experiments requiring apparatus not easily or conveniently duplicated for individual work; (*d*) experiments requiring a degree of manipulative skill not to be expected of the pupil; (*e*) experiments or exercises illustrating methods of manipulation or computation.

The question as to whether the teacher's demonstrations should precede or follow the laboratory work will depend for its answer upon the nature of the topic treated, the method of treatment, the equipment of the school, the capacity and previous training of the pupils, etc. In general, I would say that a fundamental principle or law should be developed by the teacher before the class, to be followed by verification and application in the laboratory by the pupils. If a series of minute observations has to be made in order to establish a law, these observations may well be made in the laboratory by the pupils individually, and then discussed with the teacher in the recitation or "study period."

The experiments selected by the teacher for demonstration should be the simplest that can be devised for the purpose in view. It is a mistake to use complicated apparatus with beginners, to call attention to all the details of manipulation and the multiplicity of minor phenomena that have no direct bearing on the object of the experiment. It is a good plan to call upon the more apt pupils to assist the teacher whenever possible. This gives an added interest to the demonstration, and is a stimulus to the other pupils to do their best in order to secure the coveted privilege of assisting the teacher. In this way the teacher may be able to train some pupils to be of valuable aid to him in the preparation of apparatus, and its distribution and storage.

No opportunity should be lost to impress upon the pupils the practical applications and illustrations of the principles they are studying. The basement of the modern school building usually furnishes a storehouse of useful and interesting information regarding furnaces, boilers, heating and ventilating machinery, pumps, elevators, dynamos, motors, etc. An inspection and explanation of this valuable school equipment should form a part of the demonstration work. Whenever and wherever possible, the class should visit neighboring manufacturing establishments, power-houses, etc. In fact, the field-work of "nature-study" in the lower grades may here find its counterpart and extension in the more advanced work of the upper grades. By this means an intense interest is aroused and maintained in the pupils.

2. Regarding the pupils' laboratory work, I think there can be no question of its necessity in science-teaching, even in the

elementary school. Satisfactory results in this, as in most other branches of study, can be obtained only by having the pupil *do* something, by providing that most potent means in the acquisition of knowledge—physical contact with, and manipulation of, the thing to be studied. During the first five years of the course in "nature-study" the attitude of the pupil was largely, if not wholly, that of a passive observer of given phenomena or conditions. Now in the seventh and eighth years he *creates* the conditions, adds experiment to observation, and learns to use for the first time this most powerful and fruitful of all aids in the aquisition of knowledge. He learns how to put "a question to nature, as it were, which she must herself answer—a kind of observation under definite and deliberate conditions." This being a new and untried process for the pupil, it is no wonder that he often finds it difficult to "get his bearings," unless the skilful and experienced teacher sets him right at the start. I have no sympathy with that use of the inductive method which places before the untrained pupil a physical problem to be solved experimentally, without giving him the slightest cue as to purpose, method, and results to be looked for. An unconscionable amount of time may be wasted in this way. Life is too short for this sort of thing.

Let the experiment to be performed by the pupils be most carefully considered by the teacher before assigning it. Let it be the most simple that can be devised, and absolutely within the comprehension and capacity of the pupil. Let it have some practical bearing, if possible, on his everyday life. State in clear terms the object or aim of the exercise, give explicit and minute directions (particularly at the beginning of the course), and, if necessary, call attention by means of suggestive questions to those phenomena which have a bearing on the conclusions to be drawn. After the pupil has been in the laboratory for a term, there will be less need for minuteness of directions, for he will have acquired then some skill in technique, and he will be able to observe more closely and accurately without guidance at every point. But at the beginning definiteness and clearness in statement of aim and method are essential to his later success. "Nature can only give a correct and unambiguous answer to the question you put it, when it is clearly and definitely proposed. This is very often not the case, and the experimenter loses himself in meaningless efforts, with the foolish hope that 'something may come of it.'" Aimless, desultory work in the laboratory, a mere pottering and playing with test-tubes, bottles, magnets, etc., is the worst possible introduction a student can have into the realm of physical science. On the other hand, a carefully selected series of experiments, adapted to his capacity, and performed with intelligence and earnestness, will develop in him a power of doing and thinking which no other single study can give him so well. There is no better means for training in observation, reflection, judgment, and expression than judiciously selected and carefully executed work in the laboratory. An eminent German philosopher says: "The accurate and discriminating observation of facts, supported by careful experiment, is certainly a great advantage that modern science has over all earlier efforts to attain the truth."

The kind of experiments to be performed by the pupils may be classified as follows: (*a*) experiments that verify laws demonstrated by the teacher; (*b*) experiments wholly, or largely, quantitative in character; (*c*) experiments or exercises that will impart a certain degree of mechanical skill. These may properly be repetitions of the teacher's model demonstrations.

The so-called "even front" system of laboratory work is, in my opinion, the best for elementary-school pupils. Under this plan, all pupils work at the same exercise at the same time. It requires, of course, a complete outfit of apparatus for each pupil, and hence is somewhat more expensive than the plan of assigning a different exercise to each pupil. However, the "even front" plan enables the teacher to utilize to the best advantage the all too short time at his command; it permits of general directions and explanations to the whole class, facilitates supervision, and simplifies the management of the laboratory. Indeed, since the classes in the city schools are apt to be large, this seems to me to be the only feasible plan to adopt.

One of the essential requisites in laboratory work is the keeping of a written record of the details of an experiment. This record should be made in a notebook of convenient size, and should contain the following data: number and date of experiment; object or aim; a description or diagram of the apparatus used; a statement of manipulations performed; the observations made (tabulated or graphically illustrated when possible); and the conclusions or inferences drawn from the experiment. It is best to use two pages for each exercise, reserving the even-numbered pages for a description of the experiment, and the odd-numbered pages for diagrams, tabulations, and computations. A device for facilitating the examination and criticism of notebooks, which I have seen used with some success, consists of a rubber stamp by means of which the instructor stamps the following items on the lower part of the odd-numbered pages: description; diagram; observation; inference; grammatical structure; neatness. A word or two opposite an item will serve to call the attention of the pupil to those particulars in which his record is deficient. The teacher should only indicate the errors; the pupil himself should make the corrections. Much attention should be given to the language employed by the pupil in making his records. There is a good opportunity here for emphasizing the work of the English department.

A good plan for presenting the laboratory experiments to the class is to typewrite and mimeograph the directions on a set of cards, about five by six inches, and to distribute these among the pupils during a "study period" for careful perusal, and for preparation of the form to be used in the notebooks in the following laboratory period. No portion of the time allotted to laboratory work should be given to reading up the experiment. This should always be done in a previous "study period," thus giving the full time of the laboratory period to the actual performance of the experiment.

The supervision of laboratory work is no easy matter, especially if the class be large. One teacher cannot handle effectively more than fifteen to twenty pupils, even when they are all working at the same exercise. Under the "departmental system" it is possible, by a judicious arrangement of the program, to divide a large class into two or more sections; or it may be possible to assign an assisting teacher to aid in supervision and instruction of a large class. The latter method has been tried in the school under my supervision, with excellent results. Both teachers are in close touch with the pupils and their work in the laboratory, and can give counsel and direction with facility and dispatch. These two teachers also divide between them the labor of examining and criticising the written work.

3. In the recitation periods the topics of the laboratory periods and demonstrations should be carefully reviewed and discussed, errors indicated and corrected, correlations made with the other subjects of the grades, and very simple problems given illustrating the principles or laws derived by experiment. This period should usually take the form of a "quiz," both teacher and class asking and answering questions. In this way a greater interest can be maintained in the class than by a formal recitation, and it is possible for the teacher to gauge more accurately the mental status of his class. If a textbook be used, it should be a real textbook, not a manual of "inductive questions." The textbook should supplement and extend the knowledge gained by the pupil in class and individual work. In New York a textbook is not used, but the pupil is encouraged to use books provided "for reference." In my opinion, much time could be saved if a textbook were used. I consider a good, simple textbook, if rightly used, an important aid in the teaching of physics. Without it, the pupil is likely to become possessed of a mass of isolated facts which he has not the power to correlate or classify. The textbook will provide the connecting links which he needs to unify his knowledge. The absence of a textbook increases very materially the work of the teacher, and restricts somewhat the scope of the course.

Written tests should be given about once a month. These will serve to indicate to the teacher the general grasp which the pupil has of the subject as a whole.

I cannot, within the limits of this paper, do more than merely indicate a few of the correlations of science with the other branches of study that can be made, if the teachers of the "departmental" classes work together as a unit. Mathematics, physical geography, physiology, composition, drawing, shopwork—all these departments may draw upon the science work, and the latter may in turn draw upon all the others. It is essential to the success of the whole system that such correlations be properly made. The practicability of this is one of the tests of a well-made curriculum.

It is too early as yet to say what will be the effect of this new course in science on the later science work of those pupils who enter the high school. It is safe to assume, however, that they will be better prepared to do the advanced work, even if some of the earlier work has to be repeated. There can be no doubt as to the value of this work in science to that vast majority of pupils who never enter the high school. It is for them, more particularly, that the whole course is planned. That the work is already producing practical results is evidenced by the fact that several recent inventions of considerable merit were made by elementary-school pupils. Among these is a plan to relieve the congestion at Brooklyn Bridge, and a new receiving apparatus for a wireless telegraph system. These inventors claim to have obtained their initiative and inspiration from the physics lessons in the schools.

Thus we are not only acquainting our pupils with the great truths of science, but we are creating and fostering that most desirable and productive quality, the "scientific habit of mind."